Optical production of metastable rare gases

Metastable rare gas atoms have found wide use in fields spawned by the revolution in laser manipulation of atoms, such as cold collision physics, optical lattices, atom lithography, rare isotope detection, and, most recently, Bose-Einstein Condensation (BEC). The high internal energy of the metastable atom enables both novel detection schemes in BEC studies and localized surface damage of suitable resists, and thus provides a niche beyond similar studies with ground state atoms. For these studies, the metastable rare gas atoms are generally produced in beam form by direct extraction from a DC or rf discharge. Such methods generally produce beams with a metastable fraction of less than 0.1%. Earlier metastable sources developed for molecular beam studies have used direct electron bombardment of a neutral beam in a crossed or coaxial excitation geometry, with even lower metastable fractions. For many of the applications, it is simply desirable to have an increased metastable beam fraction, but for the single atom counting of rare isotopes where the sample size is limited, it is essential.

We have investigated a new scheme for excitation of the 5s, J=2 metastable level of Kr ($5s[3/2]_{J=2}$) which can provide much higher metastable fractions (approaching 10%) and can be readily extended to other rare gases. In the scheme, an ultraviolet lamp is used to create a population of Kr atoms in the $5s[3/2]_{J=1}$ level in a gas cell. The excited atoms are then pumped to the $5p[3/2]_{J=2}$ level, using 819-nm light from a Ti-Sapphire laser, from which they decay to the metastable state with a branching ratio of 77%. We made two striking observations: 1) the laser power required to saturate the second step decreases markedly as a function of gas cell pressure, and, 2) the UV photon flux is converted with very high efficiency (≈10%) to metastable atom flux. A Monte-Carlo study of the scattering of UV photons in the cell reproduces the trends observed. The understanding achieved points to the design of a higher flux source of metastable atoms.

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